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In Situ X-ray Determination of Growth Rates for the Olivine-Wadsleyite Phase Transformation

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Beamline(s): X17B1

Introduction: The rates of nucleation and growth during the phase transformation of olivine to its high-pressure polymorphs are critical parameters for modeling the extent of metastable olivine in subducting slabs. Previous studies have been mainly concentrated on analog materials, such as Ni_2SiO_4 and Mg_2SiO_4. Data directly relevant to the earth system are lacking. This is the first report of growth rates for natural $(Mg,Fe)_2SiO_4$ system.

Methods and Materials: The starting material is San Carlos olivine. The powdered samples were dried in a vacuum oven at 160ºC for several hours prior to sample loading. Powdered NaCl (mixed with BN) was used as the pressure standard. The sample assembly was compressed to about 12 GPa at room temperature using the 250-ton LVP coupled with a T-Cup device and then annealed in the stability field of olivine at 1200ºC for 120 minutes or longer. Following hot pressing, temperature was decreased to 550ºC and kept constant while pressure was increased to the target value. Temperature was then increased again rapidly to induce the phase transformation. This is to better define the starting point of phase transformation. Time-resolved x-ray diffraction patterns were collected every 2 to 5 minutes while the sample assembly remained under the constant P, T conditions. The pressure was calculated based on the Decker's EOS of NaCl and the temperature was measured by a W-3%Re/W-25%Re thermocouple.

Results: We observed olivine to wadsleyite transformation at four different conditions. At each condition, we obtained relationship between the volume fraction transformed and the reaction time. The volume fraction transformed at given time was estimated from the integrated intensities of diffraction peaks relative to their intensities either before transformation (for olivine) or after the completion of transformation (for wadsleyite). The completion of reaction for two experiments was achieved by increasing temperature at the end of experiment. Temperature was then reduced to the experimental value upon the completion of transformation. The x-ray beam intensity has also been taken into account by obtaining the decay curve of ring current and normalizing the integrated intensities by this current. The final data sets were fitted to the kinetic law to obtain the growth rates and they are: 4.78E-11 m/s at 1050ºC and 14.7 GPa; 2.52E-10 m/s at 1110ºC and 15.1 GPa; 1.29E-9 m/s at 1160ºC and 15.6 GPa; 3.85E-9 m/s at 1207ºC and 15.7 GPa.

Conclusions: The growth rates of wadsleyite determined in the current study are significantly lower than those previously calculated based on data for analog materials. If assuming the same transformation mechanism applies in the subduction zones, one could expect even larger metastable wedges than previously suggested in subducting slabs consisted predominantly of olivine.

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